Feb. 17, 1942. L. W. MORRISON, JR 2,273,719

TELEVISION SIGNALING SYSTEM

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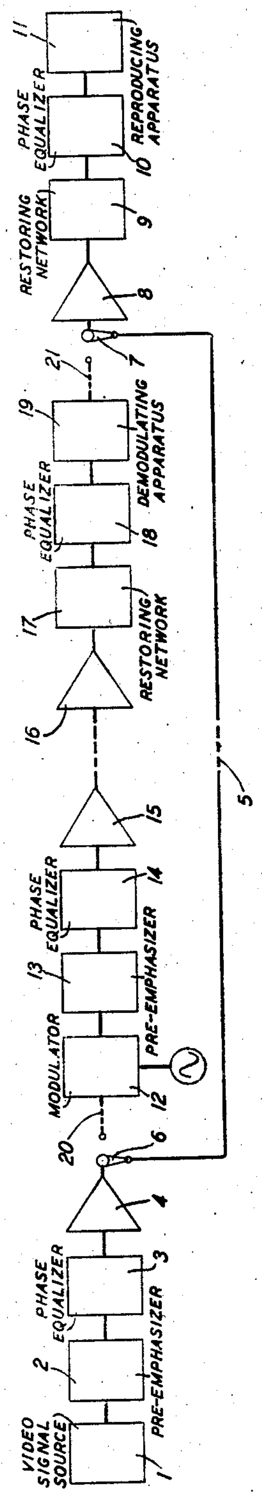

FIG. 1

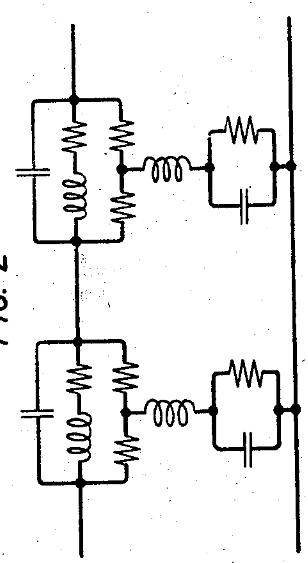

FIG. 2

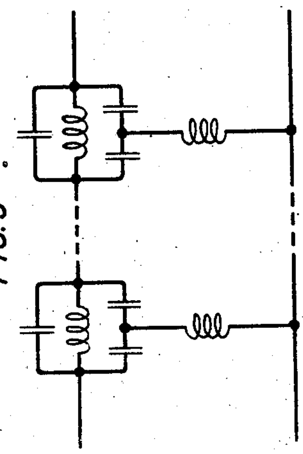

FIG. 3

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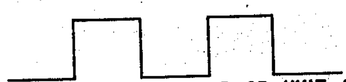
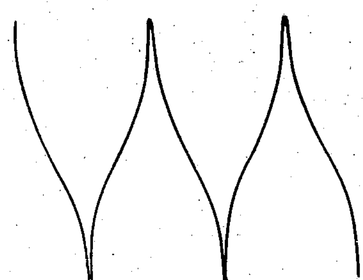
FIG. 4A



SYMMETRICAL SQUARE WAVE OF UNIT AMPLITUDE

$$I(t)=\frac{2}{\pi}\sum_{1}^{m}\frac{1}{n}\, SIN\,\frac{n\pi}{2}\, COS\, n\omega t$$

FIG. 4B

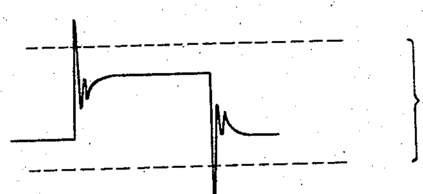


SAME WAVE AS IN FIG. 4A AFTER TRANSMISSION THROUGH 90° PHASE SHIFTER

$$I(t)=\frac{2}{\pi}\sum_{1}^{m}\frac{1}{n}\, SIN\,\frac{n\pi}{2}\, COS\left(n\omega t-\frac{\pi}{2}\right)$$

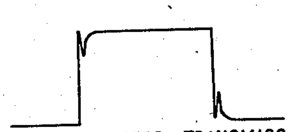
IF $m=300$, THE PEAK TO PEAK AMPLITUDE IS 4.44, AN INCREASE OF 13 db

FIG. 5A



SQUARE WAVE AFTER TRANSMISSION THROUGH A PRE-EMPHASIZER ALL PORTIONS OF THE WAVE OUTSIDE THE DASHED LINES ARE ASSUMED TO BE CHOPPED OFF BY AN AMPLIFIER

FIG. 5B



SAME WAVE AS FIG. 5A AFTER TRANSMISSION THROUGH RESTORER

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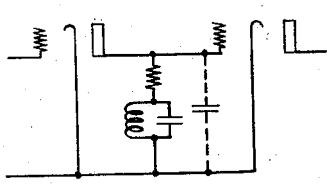
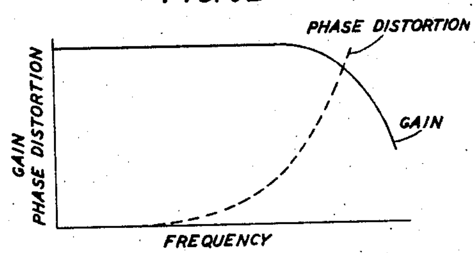
FIG. 6A



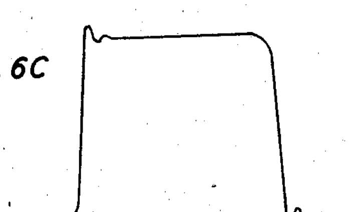
VIDEO AMPLIFIER INTERSTAGE (SIMPLIFIED)

FIG. 6B



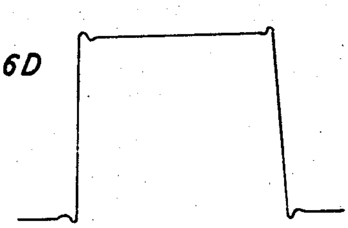
TRANSMISSION CHARACTERISTIC OF 15 AMPLIFIER STAGES OF FIG. 6A

FIG. 6C



SQUARE WAVE AFTER TRANSMISSION THROUGH 15 AMPLIFIER STAGES OF FIG. 6A

FIG. 6D



SAME WAVE AFTER TRANSMISSION THROUGH PHASE EQUALIZER

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UNITED STATES PATENT OFFICE

2,273,719

TELEVISION SIGNALING SYSTEM

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Application October 2, 1940, Serial No. 359,401

2 Claims. (Cl. 178—44)

This invention relates to electric signaling and more particularly to methods of, and apparatus for, effective transmission of television signals.

It is well known that an attenuating network may be designed to shape a composite signal wave for the purpose of emphasizing one portion of the band of frequency components relative to another and that such a network may be used in the telephone plant for pre-emphasizing or pre-shaping the signal (as, for example, in the operation of program circuits) before transmission to increase the signal-to-noise ratio over lines or cables. At the receiving point the signal can be restored to its original form by transmission through a complemental restoring network. Pre-emphasis has likewise been used in television transmission for this same purpose and also to reduce the effects of unwanted modulation when this is controlling.

In an experimental television system employing pre-emphasis certain defects in the image were noted, one of them being displaced outlines of the edges of features within the image, which defect was especially noticeable in subjects embodying a large change of brightness at the point of demarcation such as a dress shirt next to a dinner jacket. In the attempt to find the cause of the defects of this system oscillographic observations of the wave form at various points in the circuits were made and it was found that prominent peaks were present in the output current from the pre-emphasizing network. Further investigation disclosed the fact that a portion of these peaks was being cut off by the transmitting amplifier, upon which the output of the pre-emphasizing network was impressed. Oscillographic examination of the output of the restoring network showed also the presence of valleys corresponding to the chopped-off peaks. From an analysis of the action of pre-emphasizing networks it appeared that these peaks, which it seemed were due to amplitude and phase changes in the network, were so much dependent upon the phase changes that it would perhaps be possible to sufficiently well reduce them by an auxiliary phase controlling network. Subsequent experimentation with correcting networks inserted between pre-emphasizer and amplifier resulted in the finding that a material reduction in peaks could be effected with the use of a phase changing network such that there is maintained a substantially linear phase shift of the combination of this network with the pre-emphasizer over the frequency range, although it was not obvious from available knowledge of the action of electrical networks that this would be the case.

These discoveries led to the present invention, in accordance with which a network having the characteristic mentioned just above over the frequency range of a signal produced by successive line scanning, or a carrier modulated by such a signal, is used in combination with the pre-emphasizing network to reduce the peak to peak amplitude of the signal and permit a reduction in the peak load carrying capacity of the following amplifier or other device which cannot transmit these peaks without overload or the introduction of harmful distortions (or, conversely, a greater signal-to-noise ratio) and there is provided a second phase controlling network which compensates (so far as is necessary to obtain the quality of image desired) the phase shifts of the restoring network that would be complemental to those of the pre-emphasizer if the first phase controlling network which has the above-mentioned characteristic were omitted. This results in greatly improved quality of the image with respect to the edge effect mentioned above, which effect may in this way be eliminated or rendered unnoticeable, without operating the transmitting or power amplifier at very low efficiency as was found to be necessary to obtain this improvement in the image without the use of this invention.

From the above discussion of the invention it will be apparent that it has as an object the provision of a phase changing network such that the combined action of the pre-emphasizer and this network results in a substantially linear phase shift over the band of frequency components present in a signal of the kind now generally employed in television in such manner as to obtain an increased efficiency of operation in the handling of such signals.

Referring to the accompanying drawings, which illustrate an embodiment of the invention herein chosen for purpose of illustration:

Fig. 1 is a diagrammatic showing of one form of television system utilizing the invention;

Fig. 2 is a diagrammatic showing of one form of network for pre-emphasizing;

Fig. 3 is a diagrammatic showing of one form of phase changing network;

Figs. 4a, 4b, 5a and 5b are wave form diagrams hereinafter referred to in explanation of the invention;

Fig. 6a is a diagrammatic showing of an amplifier interstage connection;

Fig. 6b is a transmission characteristic of filteen amplifier stages interconnected as shown in Fig. 6a; and

Figs. 6c and 6d are wave form diagrams used in explanation of the action of the amplifier of Fig. 6a and this amplifier when associated with a phase equalizer.

Referring to Fig. 1 a video signal source 1 is followed by a pre-emphasizer 2, a phase equalizer 3 and a transmitting amplifier 4. The output of amplifier 4 may be transmitted either as such to a receiving point or as modulations of a carrier frequency. With switches 6 and 7 in the position shown the video signals are transmitted over line 5 to receiving amplifier 8, which is followed by a restoring network 9, a phase equalizer 10, and the reproducing or image forming apparatus 11. Line 5 may for example be a cable of a type which very greatly attenuates the components in the upper portion of the frequency band, so that between stages of line amplification the signal-to-noise ratio becomes excessively high. With the switches 6 and 7 placed in the horizontal position the output of amplifier 4 passes over line 20 and is impressed upon the modulator 12, the output of which passes through a second pre-emphasizer 13, a second phase equalizer 14 and an amplifier 15. The output of the latter is transmitted by line or radio to the receiving point where it is amplified by amplifier 16, the output of which is impressed upon the restoring network 17. A third phase equalizer 18 follows the restoring network and its output terminals lead to the demodulating apparatus 19. The output of the latter is impressed upon the line 21 which leads to the video frequency receiving elements 8, 9, 10, 11 as in the alternative case in which carrier transmission is not utilized. Lines 20 and 21 may be cables having the unequal attenuating characteristic above mentioned. The carrier transmission line between amplifiers 15 and 16 may be a coaxial cable and, as is often done, the modulating apparatus may consist of two series modulators utilizing separate carrier frequencies so chosen that intermodulation products which are not entirely eliminated by filters may fall within the upper part of the band of signal frequencies and be of such amplitude as to cause blemishes to appear in the image. Pre-emphasis of the components of the modulated carrier within this portion of the signal band is then advantageous.

Figs. 2 and 3 show known types of pre-distorting and phase equalizing networks respectively which may be employed to carry out the invention. These are merely given by way of illustration. Any other known suitable forms may be used for this purpose. While two network sections are shown in each of these figures it will be understood that as many sections are used as are found necessary to accomplish the desired purpose. As is well understood by those familiar with the design of such networks the various reactive and resistive elements within the networks are designed in accordance with well known principles. These are set forth for example in the article by O. J. Zobel, Bell System Technical Journal, volume 7, pages 438 to 534, July 1928.

For purpose of analysis, a television signal can be thought of as synthesized from a plurality of square waves of various lengths, amplitudes and phases. It has been found that in a well known form of television signal produced by scanning the field in 441 lines, with the usual interlace, with 30 frames per second, the high energy terms of the frequency spectrum are given by two series of components whose amplitudes decrease approximately as $1/n$, where n is the order of the term in the series. In this connection it may be noted that the spectrum of any symmetrical square wave is exhibited by Fourier series of an odd order of terms whose amplitudes are proportional to $1/n$. One of these series has a fundamental of 60 cycles per second, corresponding to the frame frequency, and the other a fundamental of 13,230 cycles per second, corresponding to the line scanning frequency. In the following discussion of Figs. 4 to 6, inclusive, there will be assumed a 13 kc. symmetrical square wave as representative of the television signal. It will not be necessary to consider the 60 cycle square wave, it being assumed that the pre-emphasizing network has a substantially flat characteristic over the relatively narrow portion of the frequency range covered by its components, as would ordinarily be the case.

Considering the problem of pre-emphasis broadly, there are two factors to be considered; namely, the signal spectrum at the transmitting terminal, and the effective noise spectrum at the receiving terminal. By the signal spectrum at the transmitting terminal is meant the relative power as a function of frequency. In connection with the noise spectrum at the receiving terminal, the term "effective noise" is used to denote the fact that the interfering effect of a given noise power may be a function of frequency. Hence the effective noise spectrum can be considered to embrace two factors, a distribution function of noise power versus frequency at the receiving terminal, and a weighting factor dependent upon the action of the human eye, which is also a function of frequency, modifying this. To obtain the best results from pre-emphasis we are concerned with minimizing the total effective noise at the receiver while keeping the peak load capacity in terms of power or amplitude at the transmitter constant. This is attained by inserting a transducer ahead of the transmitting amplifier, with possibly some additional gain, and inserting at the receiver the inverse of this transducer together with such extra gain as is necessary to bring the signal level back to its original value.

When pre-emphasis is applied to audio systems we are not concerned with the phase characteristic of the pre-emphasizer since the addition of the peak powers of the various portions of a spectrum gives the total peak power to a good approximation. In ordinary audio frequency operation the transmitting gain is readjusted after the insertion of the pre-emphasizer to make the peak output power the same as before. The receiving gain is likewise readjusted after the insertion of the complementary restorer to secure the desired transmission level.

The first thing to be noticed in video pre-emphasizing is that phase distortion changes the wave shape and hence the observed picture. Let us take for example our assumed 13 kc. symmetrical square wave of unit amplitude, as shown in Fig. 4, Fig. 4A being a representation of this wave before transmission through a phase shifter associated with a pre-emphasizer which phase shifter puts in a phase shift of 90° to all frequencies. A signal containing about 300 components has a peak to peak amplitude more than four times as great after transmission through this phase shifter as before. If the signal were left in this condition before its application to the final transmitting amplifier 4 it would be necessary to provide an increased peak load carrying capacity of roughly 13 db. in the amplifier although the average power in the distorted wave is the same as the average power in the original square wave.

Networks which heretofore mave been used as pre-emphasizers are part of a class known as minimum phase networks. All pre-emphasizers introduce phase distortion into the signal. Although this phase distortion will be taken out by the restoring network at the receiver, which in general is the inverse of the pre-emphasizer, the introduction of the pre-emphasizer may result in a considerably peaked signal at all points of the transmission path before the restorer is reached, if we assume that the load carrying capacity of some transmission element is not exceeded so that the peaks are cut off with the resultant appearance of distortion in the image.

Fig. 5A shows a square wave which has undergone pre-emphasis and whose peaks have been chopped off by an amplifier having insufficient load carrying capacity. Fig. 5B shows this wave after transmission through the restorer. These drawings have been made of the wave as observed on an oscilloscope. It is seen that the restorer introduces valleys roughly corresponding to the peaks that have been chopped off. These valleys result in the added outline edge effect noted above.

Another illustration of substantial peak reduction may be mentioned. This is illustrated in Fig. 6 which shows the effect when the wave is transmitted through a series of 15 amplifier stages employed as shown in Fig. 6A. Fig. 6B is the transmission characteristic of this series of amplifier stages. Fig. 6C shows the output wave from these amplifiers while Fig. 6D shows the wave with the phase distortion equalized. The amount of peaking above the square wave has been reduced by about one-half. While in this case the necessary increase in load capacity may be too small to warrant steps being taken to reduce the peaking, the example is given as an illustration of the general principles underlying the invention.

It is to be understood that the arrangement described above is merely illustrative and that the invention, as defined in the claims, may be utilized in a wide variety of circuit arrangements. The pre-emphasizing may take place in other apparatus, it being understood by those skilled in the art of electric transmission that unequal attenuation within a band of transmitted frequencies is, or may be, produced by many forms of networks; for example, filters and vacuum tube circuits such as amplifiers and modulators. It is to be further understood that the phase correcting networks may be placed elsewhere in the system than in juxtaposition to the pre-emphasizing networks, so long as they are located at such points that the above mentioned advantages will result.

What is claimed is:

1. In the art of signaling, the combination with electrical conducting means of means for impressing thereon signal waves, or a carrier wave modulated in accordance with such signal waves, of the kind produced by successive scanning of elemental lines of a picture or field of view, said conducting means comprising a network adapted to transmit a range of frequencies with greater attenuation in one portion of the range than in another and a phase equalizer network associated with said first network to maintain a linear phase shift of the network combination to reduce the peak amplitude of the signal wave, a third network having a transmission characteristic which is complemental to that of said first network, means for impressing the signal wave from said conducting means upon said third network, and a fourth network associated with said third network which corrects, at least in part, for non-linear phase shifts in said third network.

2. In the art of signaling, the combination with electrical conducting means of means for impressing thereon signal waves, or a carrier wave modulated in accordance with such signal waves, of the kind produced by successive scanning of elemental lines of a picture or field of view, said conducting means comprising a network adapted to transmit a range of frequencies with greater attenuation in one portion of the range than in another and a phase equalizer network associated with said first network to maintain a linear phase shift of the network combination to reduce the peak amplitude of the signal wave, means for subsequently acting upon said signal wave, which means would be overloaded without said peak amplitude reduction, a third network having a transmission characteristic which is complemental to that of said first network, means for impressing the signal wave from said amplifier upon said third network, and a fourth network which corrects, at least in part, for non-linear phase shifts in said third network.

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